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# Modelling individual preferences for environmental policy drivers: Empirical evidence of Italian lifestyle changes using a latent class approach

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### ABSTRACT

Degraded air quality severely affects the health of citizens worldwide. The design of effective policies requires exploring public preferences for environmental and air quality policy instruments. Within the EC-FP7 SEFIRA project, using a choice experiment that stresses the trade-offs between attributes, this study investigates public preferences for environmental policy drivers in Italy. The main objective is to investigate the role played by selected policy drivers in determining policy preferences, complemented by elasticity and willingness to pay estimations. Preference heterogeneity and the role of socio-economic and attitudinal variables are explored with a latent class model over 2400 respondents sampled across Italy. The results allow identifying the different role played by the policy drivers across the classes. It emerged that most of the respondents (43%) are particularly sensitive to the cost components (cost sensitive respondents). The remaining respondents instead show an important sensitivity towards personal engagement in term of changes in the mobility and eating habits (lifestyle-change sensitive respondents). However, while 29% of them perceive these habits' changes as negatively impacting on the personal utility, the other 28% of respondents translate the potential changes in the habitual behaviour of driving and eating as environmental and health benefits. Based on the modelling results, potential policies are simulated reporting respondents' reaction to selected scenarios. It shows the crucial role played by reduction of premature deaths due to atmospheric pollution and measure cost.

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## 1. Introduction

The use of behavioural modelling and related techniques to evaluate environmental and air quality policies is timely. Policies based on technical measures and technological solutions have been used successfully for many decades. However, there are increasing evidences that such measures are not up to the task of

reducing air pollution to acceptable levels. One reason for this is the indication from health effect studies that adverse effects on human health can occur even at pollutant concentrations that meet existing legal targets. Policies involving non-technical measures are therefore likely to play an increasingly important role in the future air quality management in Europe. Such policies will inevitably take into account for behavioural and lifestyle changes, assessing also individual preferences towards the main policy drivers.

The application of the discrete choice models (DCMs) in the environmental field is not *per se* a novelty, and in the last years has exponentially increased. Furthermore, the past 15 years have seen

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considerable research based on discrete choice experiments (DCEs) and their use is continues to grow (Hoyos, 2010).

In the scientific literature, DCEs have been applied mainly in the environmental field and (marginally but now increasingly) in the air quality domain in order to: i) analyse individual preferences towards a set of environmental options (such as policies) (e.g. Bristow et al., 2010; Garroda et al., 2012; Jacobsen and Thorsen, 2010; Gevrek and Uyduranoglu, 2015; Tang and Zhang, 2015); ii) predict demand (or acceptance of) a new option and define optimum pricing (e.g. Jaensirisak et al., 2005; Shen et al., 2009; Brécarda et al., 2009; Marcucci and Gatta, 2016; Marcucci et al., 2012); iii) simulate the ex-ante impact of a potential policy based on attributes' changes (e.g. Scarpa and Alberini, 2005; Andreopoulos et al., 2015; Valeri and Danielis, 2015); iv) estimate the welfare effect and the willingness to pay (WTP) for e.g. an improvement in the service quality, a decrease of the travel time etc. (e.g. Marsh et al., 2011; Chalak et al., 2012; Andreopoulos et al., 2015); and v) investigate the role played by individual beliefs and attitudes toward environmental changes (e.g. Hess and Beharry-Borg, 2012; Hoyos et al., 2015; Valeri and Cherchi, 2016).

Among the most recent and interesting applications of DCMs in the environmental field, Birol et al. (2006) supported policy makers to formulate efficient and sustainable wetland management policies in accordance with the European Union Water Framework Directive (2000/60/EC). Gevrek and Uyduranoglu (2015) studied public preferences for carbon tax attributes in Turkey deriving interesting results on the acceptability of various tax systems and cost distribution. In order to support the Danish political decision to establish the first-ever national parks, Jacobsen and Thorsen (2010) investigated if people hold preferences regarding which site to be designated as national park, separate from the preferences for its environmental functions. Shen et al. (2009) investigated if natural environmental change and transport network improvements affect individuals' choices of transport mode under an extension proposed for the Osaka (Japan) monorail loop. Andreopoulos et al. (2015) estimated changes in the perceived value of different ecological and economic services in a mountain community in Greece in terms of consumer surplus and WTP measures for different scenarios. British preferences and WTP measures for reducing GHG emissions were explored by Chalak et al. (2012), who showed that the average per-unit WTP to avoid increased GHG emissions is greater than the WTP for efforts to reduce them. Estimating hybrid choice models in the context of beach visitors' WTP for improvements in water quality, Hess and Beharry-Borg (2012) demonstrated how a latent attitudinal variable (a 'pro-intervention' attitude) helps responders' sensitivity not only to the stated choice exercise but also to questions about their attitudes. Applying the same modelling approach to a DCE conducted in the Basque Country (Spain) in 2008, Hoyos et al. (2015) evaluated the environmental awareness impact in evaluating land-use policies in a Natura 2000 Network site. Valeri and Cherchi (2016) also used a hybrid choice model to establish whether (and to what extent) habitual car use, modelled as a latent variable, affects the individual's propensity to buy a specific type of engine technology.

The human sphere and the related behavioural components are playing an increasingly significant role also for institutions in the environmental understanding and contributions to the decision-making processes. Over time, the organizations and institutions responsible for decision making, policy analysis and setting priorities have shown greater interest in applying behavioural insights to policy making in various fields, including the environment. Since 2008 the European Commission (EC) has proposed innovative proposals for the Consumer Rights Directive, for the Package Retail and Insurance-based Investment Product (PRIP) legislation (EC, 2006; Ciriolo, 2011; van Bavel et al., 2013;

Lourenço et al., 2016) and for the design of a Framework Contract for the provision of behavioural studies. Complementing these activities, the EC has started to fund research projects addressing the topic of the study presented in this paper such as the GLAMURS project (<http://glamurs.eu/>) and the CECILIA2050 project (<http://cecilia2050.eu/>). Also the OECD (2008, 2012a, 2012b) and the World Bank (2015) have emphasised the importance of identifying the behavioural elements and incorporating them into the design of policies. At the national level, centralised behavioural insight teams have been established in several countries (e.g. Germany, United Kingdom); in other countries (e.g. Denmark and France) ministries have taken the lead.

The type of research used to inform policy making typically asks citizen beings to rate/choose items on a list. This approach generally yields no more information than the fact that human tendency to desire the benefits but to avoid paying the costs; examples are provided by the EC Eurobarometer (2013) and Zvěřinová et al. (2013). That approach suffers also from a lack of information about the trade-offs among the considered options. In the context of the on-going EC-FP7 SEFIRA project, a DCE study was designed and implemented in seven European countries to analyse public preferences for potential air quality policies. The DCM approach has been used to obtain behavioural insights that will aid decision makers in the design of environmental policies. Country-specific preferences have been estimated for selected environmental policy drivers, and then compared across the seven European countries included in the SEFIRA study (Austria, Belgium, Germany, Italy, Poland, Sweden, and United Kingdom). Preliminary results of the DCMs for these seven countries are reported in Valeri et al. (2016). In this paper, we undertake an *in depth* analysis of the results obtained for one of the investigated countries (Italy) in order to better exploit observed and unobserved heterogeneity, WTP and elasticity measures, with special attention to the two policy drivers that entail changes in the respondents' personal engagement/lifestyle. Moving from the multinomial logit (MNL) model to a latent class (LC) modelling approach allowed to highlight the role played by socio-economic and attitudinal items (such as environmental awareness and intentions) in determining policy drivers preferences and WTP/elasticity measures. The empirical results derived from the LC model were used to simulate eight potential environmental and air quality policies, reporting their impact in term of choice probability changes and showing their contribution to the design of effective policies.

## 2. Methodology: choice modelling

The MNL is the base model where the linear utility function  $U$  for a generic individual  $i$  and a generic alternative  $j$  is reported below:

$$U_i(j) = \beta'x_{ij} + \varepsilon_{ij}$$

where the deterministic part of the utility is comprised of the estimated parameter  $\beta_{ij}$  for each explanatory variable  $x_{ij}$  (in our case, the policy driver), and the error term is represented by  $\varepsilon_i$ . The choice probability is then:

$$\text{Prob}(y_i = j) = \frac{\exp(\beta'x_{ij})}{\sum_{q=1}^J \exp(\beta'x_{qi})}$$

where the probability  $\text{Prob}_i$  of an individual  $i$  choosing alternative  $j$  out of the set of  $J$  alternatives is equal to the ratio of the (exponential of the) observed utility index for alternative  $j$  to the sum of the exponentials of the observed utility indices for all  $J$  alternatives, including the  $i$  –  $th$  alternative (Hensher et al., 2010;

p. 86). The MNL model is not capable of detecting random variations of individuals' preferences. Heterogeneity can be incorporated via the systematic component of utility assuming either continuous or discrete mixture structure (e.g. Greene and Hensher, 2003). The latter is preferred in the present study since, notwithstanding it is somewhat less flexible than the former, it does not require any specific assumption about parameters' distributions. Marcucci and Gatta (2012) provide a structured approach to investigate preference heterogeneity in a DCE context. A LC model assumes that estimation parameters can be approximated by a discrete mixing distribution where a small number of mass points represent segments of people with different preference structures (Boxall and Adamowicz, 2002). It consists of two sub-models, one for class allocation (where individuals are assigned to a specific class depending on their characteristics and, possibly, the alternatives in the choice set), and one for within class choice (where class-specific choice probabilities are computed conditional on the tastes within that class).

The choice probability is the expected value, over classes, of the choice probability within each class. More in detail, for  $N$  classes, the model is specified as follows:

$$\text{Prob}(y_i = j | \text{class} = q) = P(j|n)P(n) \\ = \frac{\exp(\beta'_n x_{ji})}{\sum_{q=1}^J \exp(\beta'_n x_{qi})} \sum_{n=1}^N \left( \frac{\exp(\phi'_n k_i)}{\sum_{n=1}^N \exp(\phi'_n k_{qi})} \right)$$

where  $P(j|n)$  is the probability that an individual  $i$  assigned to class  $n$  chooses alternative  $j$  (same calculations as MNL); the class probabilities can be viewed as functions of the socio-economic variables  $k$  whose coefficients  $\phi_n$  are normalised to zero. The choice of the number of classes to be estimated is not a trivial one, since conventional tests cannot be employed. When no *a priori* information about the existence of specific groups, various elements can be considered to determine the optimal number of classes ranging from model robustness (e.g. information criteria statistics) to plausibility of model results (e.g. the sign, significance and magnitude of the estimated parameters). In the proposed LC model, *non-attendance* strategies for attributes have been considered when ignored by the respondent so the related attributes have a parameter set to zero (as done by Hensher et al., 2005; Scarpa et al., 2008; Hensher, 2008).

### 3. Data and survey features

#### 3.1. Questionnaire

After a testing phase conducted in the spring 2015, preferences regarding environmental and air quality policies were collected in June 2015 among a sample of 2400 Italian citizens (i.e. 9600 numbers of observations) through a *computer-assisted web interviewing* (CAWI) technique. Interviews have been created using NIPO software which allowed us to randomise the positioning of the policy drivers and of the alternatives in the choice experiments (for each block of the design) as well as the positioning of the attitudinal statements inside each own category.

The questionnaire was divided into three sections. The first part was used to identify the *respondent's profile*, collecting information regarding the socio-economic status of the respondent and of her/his family such as age, gender, education level, current employment, marital status, household composition and net family income. Mobility and eating habits have also been investigated due to experimental design needs. The socio-economic information has been used for both profiling the interviewed sample and detecting possible different preferences in the modelling process. In the second part of the questionnaire four *unlabelled choice*

*experiments* have been presented. Before asking to the respondents to make a compensatory evaluation among the two policy alternative options included in each choice task, an introductory section has been provided where the context of environmental and air quality policies is described along with the specific definition of the key terms as well as the policy drivers (in technical term, attributes) characterising the alternatives. In the last section, *attitudinal data* have been collected. A particular advantage is the consideration of certain latent factors (such as environmental perception and awareness, social network, social trust, health awareness) that allow to better exploit individual heterogeneity through latent factors (e.g. Hoyos et al., 2015; Valeri and Cherchi, 2016). For more information on the questionnaire see Avataneo et al. (2014).

#### 3.2. Experimental design and sampling

The identification and selection of relevant attributes (here, policy drivers) that characterise alternative air quality policy measures is a crucial step in the design of DCE survey, especially when the results are to be used for policy purposes. Complemented by a literature review (of which the main studies include Pridmore and Miola, 2011; de Groot and Schuitema, 2012; Steg and Schuitema 2007; Steg et al., 2006), an interdisciplinary effort involving competencies from the physical and social sciences has allowed narrowing a list of 20 potential drivers relevant to environment and air quality (such as reduced mortality, reduced morbidity/health, equity/fairness – who pays –, environmental fairness, impact on competitiveness, impact on employment, change of lifestyle, privacy reduction etc.). These drivers have been grouped into homogeneous clusters to select, at the end, those that the present case study indicated were the most representative. Special attention was paid to those drivers affecting the individual sphere towards monetary elements, personal engagement, public health and social fairness. The five policy drivers included in the final choice experiment are the following:

1. Cost of the measure (hereafter, *measure cost*): is the annual cost you will have to bear as a consequence of the implementation of the environmental policy.
2. Required changes in your mobility behaviour (hereafter, *mobility habits*): is the decrease required in the use of polluting means of transportation (car/motorcycle), compared to your present use of these vehicles.
3. Required changes in your eating habits (hereafter, *eating habits*): is the decrease required in the consumption of beef, pork, lamb and horse meat or of milk and dairy products, compared to your present consumption.
4. Reduction of premature deaths (hereafter, *premature deaths*): the impact of the policy on the reduction of premature deaths caused by the presence of particulates and ozone.
5. Distribution of the measure costs (hereafter, *'polluters pay more' principle*): indicates how the costs of the environmental measure must be distributed to the community.

According to European Topic Centre on Air and Climate Change (ETC/ACC) on behalf of the European Environment Agency (EEA), atmospheric pollution severely affects human health and in 2012 was responsible for 455,000 premature deaths in Europe, as a consequence of exposure of the population to harmful pollutants such as fine particles (PM), nitrogen dioxide (NO<sub>2</sub>) and ozone. The agro-food industry, and in particular the animal food production chain, with emissions of livestock ammonia (NH<sub>3</sub>) and reactive nitrogen (Bouwman et al., 2013; Westhoek et al., 2014), and the transport sector with vehicle emissions of primary PM, NO<sub>2</sub>, and volatile compounds (see e.g. Carslaw et al., 2011; Pallavi and



Harrison, 2013), are key drivers of air pollution. Chemical reactions occurring in the atmosphere involving livestock NH<sub>3</sub> and NO<sub>2</sub> from traffic yield secondary fine particles, increasing the negative effects of air pollution (Fuzzi et al., 2015). Hence, it is clear that modifying the dietary and mobility habits of individuals would benefit human health by improving ambient air quality (Tilman and Clark, 2014). Maione and Fuzzi (2013) reviewed recent scientific findings in this field.

The attribute levels are combined into potential policy options and four binary choice experiments per interview are built. In each choice experiment, two hypothetical and equivalent (in terms of air quality impact) policy have been presented. To allow for a rich variation in the combination of attribute levels, a blocking strategy is adopted preparing four versions of the survey form. There are different types of experimental designs, each characterized by specific pros and cons (Louviere et al., 2000); efficient multi-stage designs are proved to be very useful in the case of small samples (Gatta and Marcucci, 2016). In the present study, sample size was not an issue and thus we opt for an orthogonal design. So, an unlabelled randomised design, based on the properties of minimal level overlap, level balance and orthogonality, with the blocking option has been estimated using the Sawtooth/CBC software. Details of the experimental design are summarized in Table 1.

Given the research objectives and the types of the policy drivers selected, the target population has been defined as people who both use cars/motorcycles for their urban movements and consume meat and/or milk or dairy products more than four days per month. A stratification strategy has been adopted considering specific socio-demographic and geographical elements. Quotas are set for age, gender and geographical area crossed by level of urbanisation (the latter variable is based on the EU classification of NUTS3, called 'urban-rural typology', into three categories: 'predominantly rural', 'intermediate' or 'predominantly urban' regions). Since there are no official data available on the distribution of the universe of this target population, data on resident population 18+ were used as a proxy, to set the above mentioned quotas.

The values visualised by the respondents regarding the two policy drivers linked to a behavioural engagement of respondents (e.g. reductions in mobility and eating habits) reflect a pivoting strategy based on the *status quo* value stated by each respondent as declared during the administration of the questionnaire and confirmed before the choice experiments.

## 4. Empirical results

### 4.1. Descriptive statistics

This section reports the descriptive statistics of the socio-economic and demographic variables used in the modelling

exercises, and also of other elements related to individual's attitudes (e.g. environmental awareness and intentions) and lifestyle habits towards environmental-related topics. Table 2 summarise these data. The average respondent is 45 years old, is educated at least than the upper-secondary school level, has more than €15,000 in annual (family) net income, lives in a household consisting of more than one member, and has no more than two children. With regard to respondents' study-related habits declared as *status quo*, the average respondent uses a polluting transport mode on 22 days each month, and consumes red meat and/or milk and dairy products on 18 days (Table 2). Fig. 1 reports details on respondents' mobility and eating habits of the (here, multiple choices were allowed). While for the eating habits all the proposed categories were generally chosen, for what the mobility habits were concerned, the use of the car, either as a driver and a passenger, is the prevailing transport mode.

### 4.2. Multinomial logit model

The estimation results for the MNL model are reported in Table 3. It is characterised by a good fit to the data (0.23 pseudo-R<sup>2</sup> and −5,771.19 of LL). As expected the measure cost policy driver is negative and significant. The reduction of premature deaths due to atmospheric pollution and the adoption of the 'polluters pay more' (rather than the 'poor pay less') principle has a positive effect on the respondents' utility function. Considering the range of the tested attributes-levels (reported in Table 1), the policy drivers related to the personal engagement of respondents (i.e. reduction in the mobility and eating habits) do not seem to affect the choice of an environmental policy.

Elasticities can be calculated to measure attribute importance. The elasticity  $E_{X_{ik}}^{P_i} = \frac{\partial P_i}{\partial X_{ik}} \cdot \frac{X_{ik}}{P_i} = (1 - P_i)X_{ik}\beta_k$  is the percentage variation in the probability  $P_i$  of choosing alternative  $i$  due to a percentage change in a specific independent variable  $X_{ik}$ .

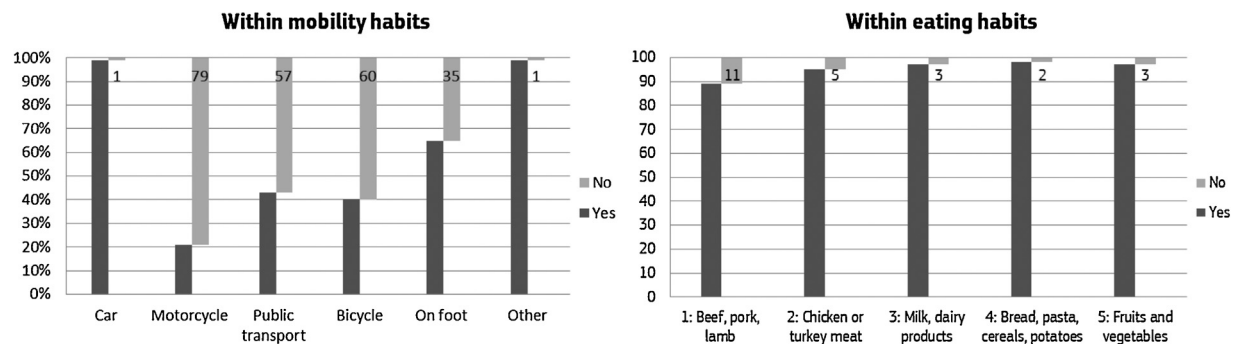
Table A1 (Appendix A) reports elasticities calculated via probability weighted sample enumeration for the significant policy drivers according to the MNL model. The elasticities linked to a 10% increase of the measure cost and of premature deaths and to get 'polluters pay more' principle (in the latter case arc-elasticity, based on the average of the before and after probabilities and attribute levels, is calculated) are −12%, 26% and 0.11%, respectively. Segmenting by socio-economic variables, the elasticity measures vary across policy drivers and socio-economic items. For instance, with respect to the reduction of premature deaths caused by the atmospheric pollution a 10% increase would lead to a 29% increase in choice probability for the most educated respondents, and 28% for women and family with more than one member. While there is a clear different reaction to changes in the "measure cost" policy driver when considering the gender variable (women −12% and men −8%), within the family size

**Table 1**  
Characteristics of the experimental design.

Policy attribute (units) [no. of levels]	Mobility habits (days/month)	Eating habits (days/month)	Fewer deaths (number/year)	Cost distribution
Measure cost (€/year)	(days/month)	(days/month)	(number/year)	–
[4]	[3]	[3]	[3]	[2]
Description of levels				
No cost	No reduction	No reduction	50,000 fewer premature deaths annually	Those who pollute more, pay more
€10 annually	25% fewer days/month	25% fewer days/month	125,000 fewer premature deaths annually	The poor pay less
€25 annually	50% fewer days/month	50% fewer days/month	250,000 fewer premature deaths annually	–
€50 annually	–	–	–	–

**Table 2**  
Descriptive statistics.

Variable	Description	Sample statistics
<i>Socio-economic</i>		
Gender	F	52%
	M	48%
Age	Average	45 years
	Min	18 years
	Max	87 years
Education level	Until upper secondary school	67%
	Higher education	33%
Family income	Yearly household income of no more than €15,000	17%
	Yearly household income exceeding €15,000	83%
Family composition	No more than 2 children (less than 19 years old)	87%
	At least 3 children (less than 19 years old)	13%
Family size	Household has 1 member	5%
	Household has more than 1 member	95%
<i>Lifestyle</i>		
Mobility habits	Stated monthly use of automobile or motorcycle	22 days
Eating habits	Stated monthly consumption of meat and/or dairy	19 days
<i>Attitudinal</i>		
Environmental awareness	'Environmental protection will provide a better world for me and future generations'	<i>I totally disagree</i> 2% <i>I disagree</i> 1% <i>Irrelevant</i> 5% <i>I agree</i> 35% <i>I totally agree</i> 56%
Environmental intention	'Within the next 3 months, I want to undertake an environmentally friendly.'	1% 2% 17% 54% 26%



**Fig. 1.** Detailed use of mobility and eating habits of respondents.

Notes: car and motorcycle categories are considered when the respondent is a driver or a passenger; public transport includes bus, tram, underground, train and ferry boat; dairy products include butter, yoghurt and cheese.

categories there are slight differences in the elasticity values (–15% and –18% for one member and more than one member households, respectively).

Additionally, one could calculate WTP measures representing the amount of money an individual would forego to achieve a

**Table 3**  
Econometric results of the MNL model.

	Coefficient	t-test
<i>Attributes</i>		
Measure cost	–0.0119	–13.94
Mobility habits	–0.0007	–0.24
Eating habits	–0.0012	–0.31
Premature deaths	0.0049	22.68
'Polluters pay more' principle	0.0428	3.56
<i>Statistics</i>		
Log-likelihood	–5,771.19	
Pseudo- $R^2$	0.2300	
No. of parameters	5	
No. of respondents	2301	
No. of observations	9204	

unitary increase in an attribute positively impacting utility. The WTP for a given policy driver  $\beta_j$  can be obtained dividing its marginal coefficient by the negative coefficient on the monetary variable  $\beta_c$  (in this analysis, the measure cost) as follows:  $WTP_j = \frac{\beta_j}{\beta_c}$ . Table A2 (Appendix B) reports the results of the estimated WTP measures for the significant policy drivers. The baseline value, calculated without performing any socio-economic segmentation, is provided at the top of the table. On average, respondents would be compensated by 0.41€ (with a confidence interval ranging from 0.35 to 0.48) for 1000 premature deaths reduction. The WTP confidence interval is based on the Delta method. An in-depth discussion of the various methods to calculate confidence intervals for WTP measures is given in Gatta et al. (2015). Segmenting by socio-economic variables, the value increases for instance to 0.83€ for more educated respondents (those who have bachelor and postgraduate degrees), to 0.53€ for family with many children (>3), and to 0.52€ for men (while women report a 0.35€). The adoption of the 'polluters pay more' principle is evaluated on average 3.57€ (with a confidence interval ranging from 1.54 to 5.66). This value increases to 13.79€ for family

**Table 4**  
Econometric results of the LC model.

	Class 1		Class 2		Class 3	
	Coeff.	t-test	Coeff.	t-test	Coeff.	t-test
<i>Policy attributes</i>						
Measure cost	−0.0138	−6.09	−0.0148	−3.84	0.0017	0.33
Mobility habits	0.0225	1.94	−0.0961	−4.57	0.1324	5.04
Eating habits	0.0186	1.48	−0.0854	−4.72	0.1287	4.26
Premature deaths	0.0013	1.89	0.0059	5.92	0.0155	8.67
'Polluters pay more' principle	−0.1733	4.05	0.3811	4.97	0.2496	3.03
<i>Segment membership function</i>						
Intercept	5.4550	6.03	−0.5620	−0.56	−4.8930	−5.56
Age	−0.1163	−2.27	−0.0142	−0.31	0.1305	3.31
Environmental awareness	−0.8233	−4.84	0.2304	1.25	0.5929	3.82
Environmental intention	−0.0107	−0.09	−0.2252	−2.14	0.2359	2.86
Education level	−0.2715	−2.30	0.0384	0.36	0.2331	2.38
Family income (×1000)	−0.2504	−2.57	0.2204	3.21	0.0300	0.43
<i>Statistics</i>						
Log likelihood	−4,886.87					
Pseudo-R <sup>2</sup>	0.48					
Class probability	42.86%		28.97%		28.17%	
Akaike information criterion	9828					
No. of parameters	27					
No. of respondents	2301					
No. of observations	9204					

with more than one member, to 7.36€ for more educated respondents, and 7.08€ for >45 years old respondents.

#### 4.3. Latent class model

The presence of preference heterogeneity by using a LC model specification has been investigated as well. The estimation results are summarised in Table 4 where three different classes are determined. The LC model specification reported is characterised by a quite good fit to the data (0.48 pseudo-R<sup>2</sup>), indicating the existence of multiple segments in the sample characterised by different preference structures. The number of classes was determined accounting for information criteria statistics, parameter significance and plausibility of results. All these criteria, jointly considered, suggest the presence of three separate classes of respondents each characterised by a different behavioural profile. Although the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) improve as the number of segments increases, the marginal improvement in the AIC and BIC diminishes after the three-segment model. Therefore, three-segment LC model is selected as the best fit to the data.

Table 4 shows the expected values for the covariates in the different classes. The top panel of the table reports the estimated coefficients of the policy drivers for each class, while the lower part shows the socio-economic and attitudinal variables explaining class membership. Across the three classes, the policy drivers play a different role (especially those related to personal engagement). In Class 1 the policy drivers behave in line with the MNL model results, except the premature deaths attributes that becomes not significant. The members of this class (equal to the 43% of the sample) are sensitive to the measure cost and at the 'polluters pay more' principle to distribute policy cost to the community. While in this class, respondents are not sensitive to lifestyle changes (as defined above), in Class 2 an important and negative sensitivity to reductions of mobility and eating habits has been found. Respondents belonging to this class keep aversion to changes in the measure cost policy drivers while report a positive sensitivity to the improvement in the reduction of premature deaths. By

contrast with the previous class (Class 1), these respondents (equal to the 29% of the sample) prefer the 'polluters pay more' principle to distribute policy cost to the community (instead of the 'poor pay less' principle preferred by the respondents belonging to Class 1). In the last class (Class 3) members (equal to the 28% of the sample) are not sensitive to the measure cost, while are (highly) and positively sensitive to lifestyle changes in term of reduction of mobility and eating habits, translating these reductions as environmental and health benefits.

In order to describe the class membership both socio-economic and attitudinal covariates have been used. Table 4 highlights the three class profiles. For interpretation purpose one should note that the coefficients reported are based on effects coding, thus the values for all classes sum to zero. The members of Class 1 are young people, with a low family income level<sup>2</sup> (less and equal to 15,000 € per year), low education level, negative sensitivity towards the environmental protection and without the intention to take, within the next three months, an environmentally friendly behaviour. In Class 3 there are no-young people, with a high family income level (above 15,000 per year), high education level, positive sensitivity towards the environmental protection and with positive intentions to take within the next three months an environmentally friendly behaviour. Lastly, the members' profile of Class 2 is a mix of the two previous respondents' profiles.

In Table 5 the significance of the estimated coefficient (Wald overall tests) is reported in order to determine if the coefficients for these outcome variables in the model are significantly different from each other across classes. Results show that all the policy drivers are significantly different from each other across classes.

<sup>2</sup> The household income has been modelled as proposed by 'OECD-modified equivalence scale' proposed by Hagenaars et al. (1994) and usually used also by Institution in the social science. In practise, the yearly net household income is divided by the number of family component calculated assigning a value of 1 to the household head, of 0.5 to each additional adult member and of 0.3 to each child. This variable may exploit potential economies of scale in household monetary decisions.

**Table 5**

Significance of the estimated coefficients (LC model).

Policy attributes	Wald test	p-value
Measure cost	7.778	0.0200
Mobility habits	56.116	6.5e-13
Eating habits	54.885	1.2e-12
Premature deaths	69.301	8.9e-16
'Polluters pay more' principle	79.629	5.1e-18

#### 4.4. Simulations of potential policies

This section provides scenario analyses to clarify the potentialities of the proposed approach while providing useful information to policy makers. Simulations are based on the LC model results where individual-specific parameter estimates are calculated. The outcome of each policy scenario, which is characterised by specific attribute levels, is determined by averaging individual choice probabilities. The results for simulating eight potential policy scenarios are reported in Table 6.

First consider the following *baseline* policy: its yearly cost to the individual is €10, it results in 50,000 fewer premature deaths, it adopts the 'poor pay less' principle as regards costs distribution to the community, and it does not entail any changes in mobility and eating habits. Overall, the baseline's choice probability is equal to 43%.

Scenarios from 1 to 5 show the impact on choice probabilities when changing one at a time the five policy drivers. When simulating the potential effects of each attribute one notices that the efficacy of each instrument varies from case to case thus providing relevant information concerning the priority that could be assigned to each policy driver given its potential impact. Requiring lifestyle changes (i.e. reducing mobility or eating habits by 25%) is associated with an increase in the choice probability of 14% and 15% (scenario 1 and 2), and of about 19% when (scenario 3) measure cost is set to zero. Still greater effect would result from the adoption of the 'polluters pay more' principle (choice probability +28%, scenario 4), and even higher in the case of a reduction of 125,000 premature deaths (choice probability +39%, scenario 5).

The simulation performed in the scenario 6 reveals that a policy that costs more (50€) but is more effective (125,000 premature deaths) is still preferred to the baseline (67% vs. 43%, respectively). It is also possible to find a policy with a higher choice probability with respect to the baseline and characterized by a higher cost (50€) where mobility and eating habits are reduced (–50%) and the 'polluters pay more' principle is adopted without changes in premature deaths (scenario 7).

Finally, the policy mix simulated in the scenario 8 reports the greatest impact on choice probability according to the experimental design proposed. This result (93% of choice probability) is obtained by setting each policy driver at its best level.

Policy makers can exploit the results obtained and simulate any interesting scenario so to forecast the likely reaction that people would have, based on their specific preferences. The modelling results may be used to: obtain *ex-ante* the implications deriving from possibly different compositions of alternative policy changes (as by Gatta and Marcucci, 2014) propose a similar approach to define improving and equally impacting policy mixes in the case of urban freight transport policy); 2) design and implement *ad hoc* decision support system (DSS) for the different levels of governance (e.g. national and regional) to help the decision-making processes (as by Valeri, 2013 in constructing a DSS for inter- and intra-modal transport competition in the Rome-Milan corridor).

#### 5. Policy implications and conclusions

Environmental and air quality policies based on technical measures and end-of-pipe solutions have been used successfully for many decades. However, there is increasing evidence that such measures will not be enough to reduce air pollution to acceptable levels. Policies involving non-technical measures are therefore likely to play an increasingly important role in the future air quality management in Europe. Such policies will inevitably involve behavioural and lifestyle changes.

Discrete choice models have previously been applied to examine individual preferences regarding particular air quality policy drivers. The present paper reports an *in depth* analysis of the results obtained for one out of the seven investigated countries (Italy) in the pilot study conducted within the SEFIRA EU-FP7 project in order to better exploit individual heterogeneity.

Using a LC modelling approach, it has been possible to highlight the different role played by the policy drivers across the classes. It emerged that respondents belonging in Class 1 are particularly sensitive to the cost components (cost sensitive respondents). This is explained by the highest and negative impact of the measure cost and 'poor people pay less' principle. The members of the last classes (Class 2 and Class 3) instead show an important sensitivity towards personal engagement in term of changes in the mobility and eating habits (lifestyle-change sensitive respondents). However, while Class 2' s members perceived these habits' changes as negatively impacting on the personal utility, Class 3' s members translate the potential changes in the habitual behaviour of driving and eating as environmental and health benefits.

**Table 6**

Overview of the policy simulations.

Attribute	Baseline	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Measure cost	€10/year	€10/year	€10/year	No cost	€10/year	€10/year	€50/year	€10/year	No cost
Mobility habits	No change	No change	25% reduction	No change	No change	No change	No change	50% reduction	50% reduction
Eating habits	No change	25% reduction	No change	No change	No change	No change	No change	50% reduction	50% reduction
Fewer deaths	50,000	50,000	50,000	50,000	50,000	125,000	125,000	50,000	250,000
	fewer	fewer	fewer	fewer	fewer	fewer	fewer	fewer	fewer
Cost distribution	'Poor pay less'	'Poor pay less'	'Poor pay less'	'Poor pay less'	'Polluters pay more'	'Poor pay less'	'Poor pay less'	'Polluters pay more'	'Polluters pay more'
<b>Choice probability</b>	<b>43%</b>	<b>57%</b>	<b>58%</b>	<b>62%</b>	<b>71%</b>	<b>82%</b>	<b>67%</b>	<b>57%</b>	<b>93%</b>
Scenario vs. Baseline:		+14%	+15%	+19%	+28%	+39%	+24%	+14%	+50%



The role of socio-economic variables in explaining individual heterogeneity has been also pointed out through segmentation analysis of elasticity and willingness-to-pay measures.

Using the empirical results of the LC model, eight potential environmental and air quality policies have been simulated reporting their impact in term of choice probability changes and showing their contribution in the policy design. This can help in forecasting the likely reaction that people would have, based on their specific preferences. Overall, the results show that, based on how scenario are designed, changes in the reduction of premature deaths due to atmospheric pollution and the measure cost policy drivers are those that more impact on choice probability of a potential air quality policy. The results obtained entrust policy makers with quantitative and strategically relevant results useful for policy making.

Future research to develop the methodology is possible along several dimensions, as follow: 1) testing for the possibility of non-linear attribute variation effects (Gatta and Marcucci, 2015); 2) complementing the current study by estimating WTP space measures (Train and Weeks, 2005); 3) integrating other modelling tools and/or integrated assessment models (Fabrizi et al., 2012); 4) implementing a hybrid choice model that deals more thoroughly with latent factors (Hoyos et al., 2015; Valeri and Cherchi, 2016); and, 5) including more countries surveyed by the SEFIRA DCE so as to generate geographical comparisons.

From a policy content point of view, this work has explored only a few possible applications of the methodology to air quality policy questions. In future policy makers could use DCMs to

explore a range of important issues. The recent concern over diesel emissions is one example; the models described here could explore the likelihood of changes in purchasing decisions to move away from diesel to alternative fuel cars (Carmeci and Valeri 2015; Valeri and Cherchi, 2016). Another example of possible application concerns the acceptability of policies to mitigate climate change which can have adverse effects on air quality, namely the use of biomass (wood) in residential and community heating systems. The use of these socio-economic modelling techniques in conjunction with physical/chemical modelling of technical scenarios and policies can provide important synergies for policy makers in addressing future air quality and climate change issues.

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## Appendix A.

### Socio-economic segmentation of elasticities.

**Table A1**  
Overview of the elasticity measures (MNL model).

Socio-economic category	Type of policy change: Baseline value: Socio-economic sub-category	Policy drivers		
		Measure cost Decrease –12%	Premature deaths Increase 26%	'Polluters pay more' Decrease 0.11%
Gender	Only women	–15%	28%	0.04%
	Only men	–8%	25%	0.16%
Income level	Yearly household income of no more than €15,000	–12%	26%	0.19%
	Yearly household income exceeding €15,000	–14%	25%	–
Age	≤44 years	–14%	24%	–
	≥45 years	–14%	28%	0.28%
Education level	Until upper secondary school	–12%	25%	–
	Higher education	–11%	29%	0.04%
Family composition	No more than 2 children (less than 19 years old)	–12%	26%	0.10%
	At least 3 children (less than 19 years old)	–9%	26%	–
Family size	1-member household	–15%	24%	0.31%
	>1-member household	–18%	28%	2.20%

## Appendix B.

### Socio-economic segmentation of WTPs.

**Table A2**

Overview of the WTP measures (MNL model).

Socio-economic category	Unit: Baseline value: Socio-economic sub-category	Policy drivers	
		Premature deaths €/1000 deaths	'Polluters pay more' Adoption
		−0.41	3.57
Gender	Only women	−0.35	–
	Only men	−0.52	6.99
Income level	Yearly household income of no more than €15,000	−0.42	5.14
	Yearly household income exceeding €15,000	−0.34	–
Age	≤44 years	−0.32	–
	≥45 years	−0.50	7.08
Education level	Until upper secondary school	−0.38	–
	Higher education	−0.83	7.36
Family composition	No more than 2 children (less than 19 years old)	−0.41	3.40
	At least 3 children (less than 19 years old)	−0.53	–
Family size	1-member household	−0.32	5.37
	>1-member household	−0.25	13.79

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